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AN INVESTIGATION OF 18 NiCoMo (300)

MAR-AGING STEEL FORGINGS

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GENERAL DYNAMICS | FORT WORTH

REPORT NO: FZM-2608
DATE: 10 MAY 1962

AN INVESTIGATION OF 18
NiCoMo (300) MAR-AGING
STEEL FORGINGS

OBJECTIVE:

To completely evaluate new high strength steels for use in critical applications, such as aircraft landing gears.

SCOPE:

To determine the mechanical properties of candidate alloys when used in heavy forged sections.

Testing to include:

1. Notch Toughness

Notch toughness testing of fatigue cracked, centrally notched specimens ($K_t = 17$) at R.T. and -65°F taken from 4" x 12" billets.

2. Heat Treat Response

Heat treat response tests to determine effects of aging temperature and time and grain direction within forging on F_{tu} , F_{ty} , R.A., $\%e$, and F_{tnu} ($K_t = 6.5$).

3. Fatigue

Fatigue properties in longitudinal and transverse directions tested in axial tension-tension fatigue. SN curves will be developed for stress concentration factors of 1 and 2.

4. Low Cycle Fatigue

Low cycle - high stress fatigue tests will be conducted to obtain failures between 0 and 100 cycles. The effect of environment will be studied.

5. Stress Corrosion

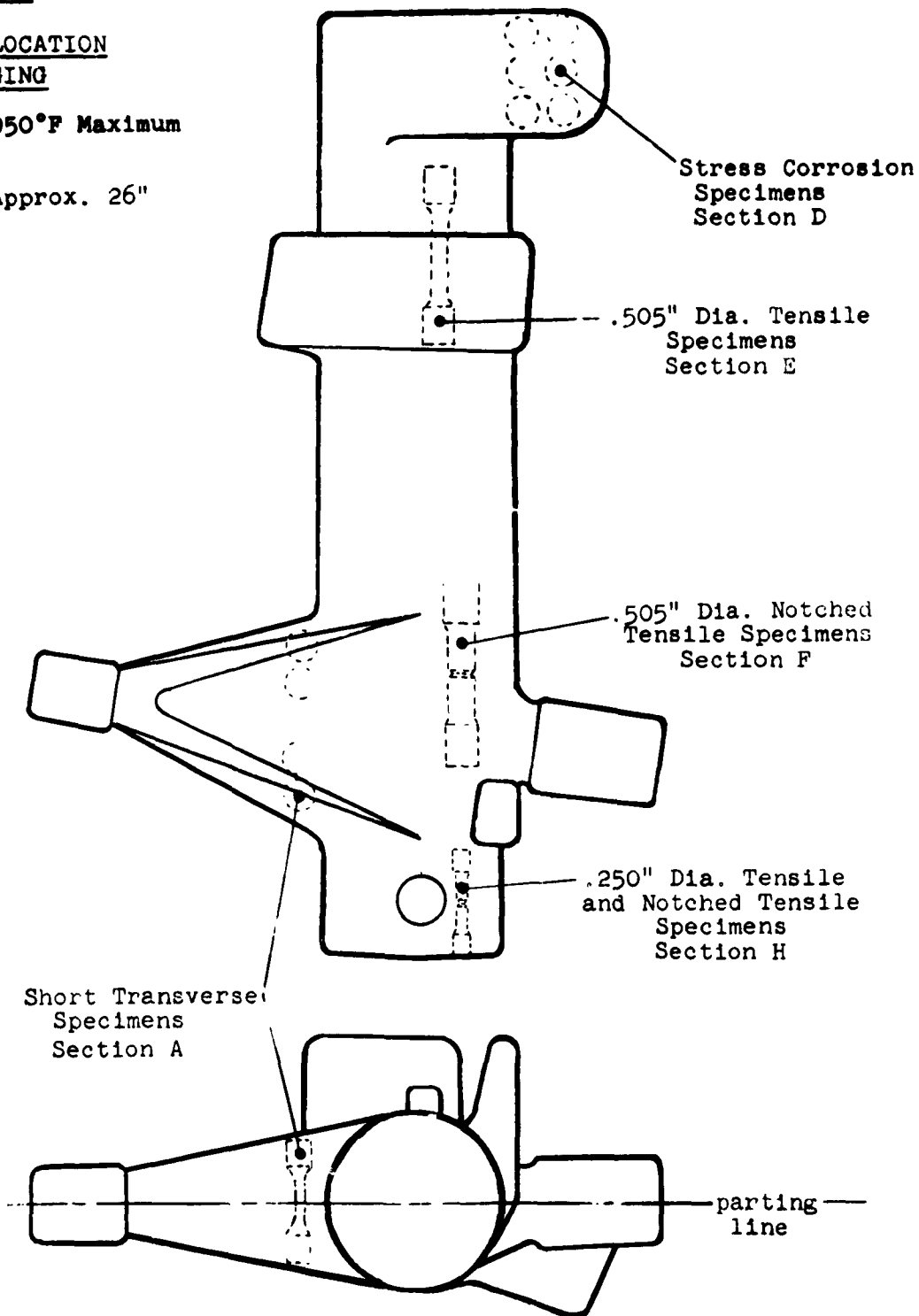
Stress corrosion data will be generated on axial loaded specimens using an alternate immersion 5% salt water solution-air test. Both smooth round specimens (short transverse direction) and sheet specimens cut from the long transverse direction of the 4" x 12" billet will be tested. A fatigue notch .030" long will be produced in one face of the sheet specimens to provide stress concentration.

FIGURE 1

SPECIMEN LOCATION
IN FORGING

Forged at 1950°F Maximum

Length - Approx. 26"



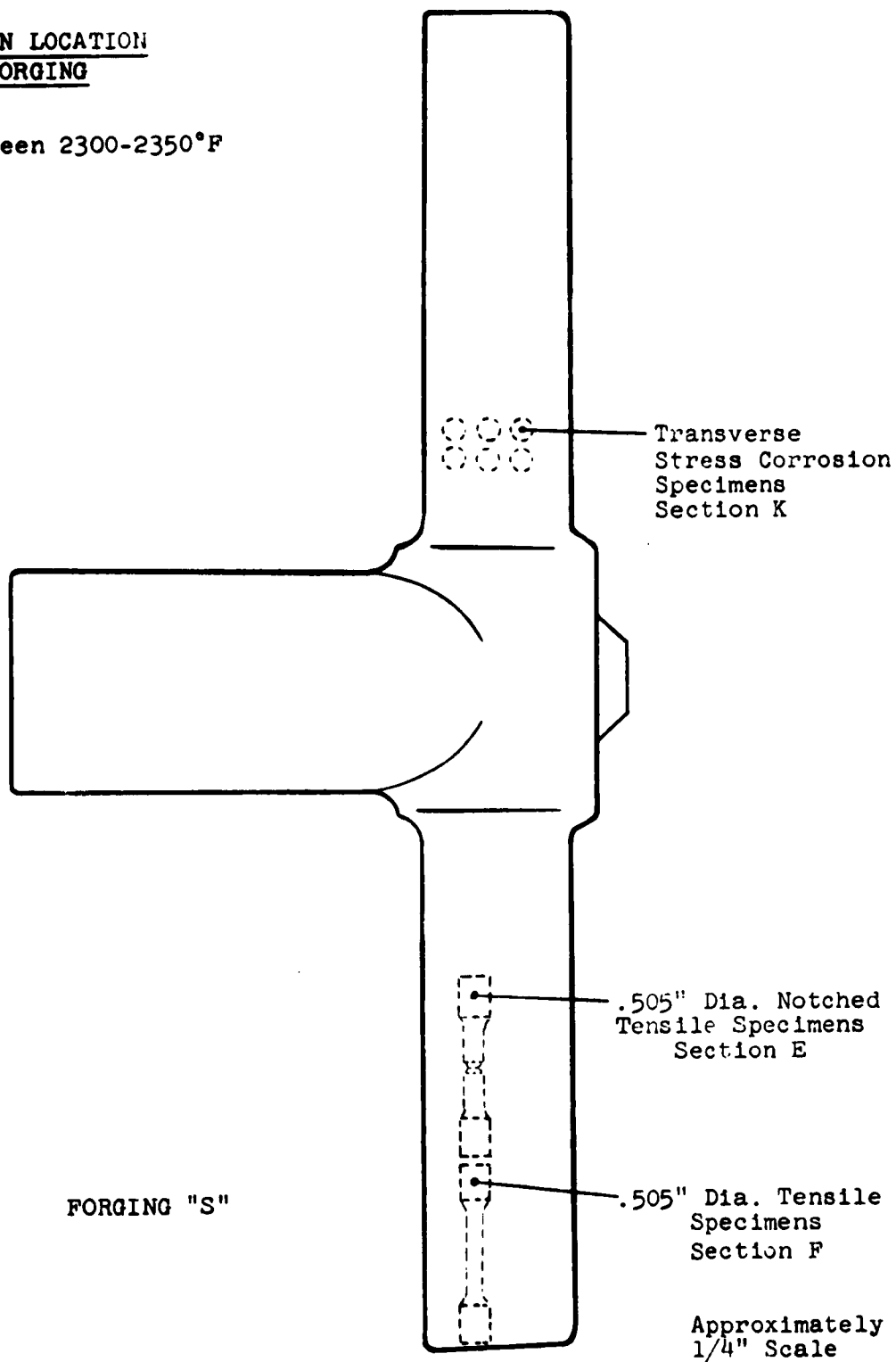
FORGING "W"

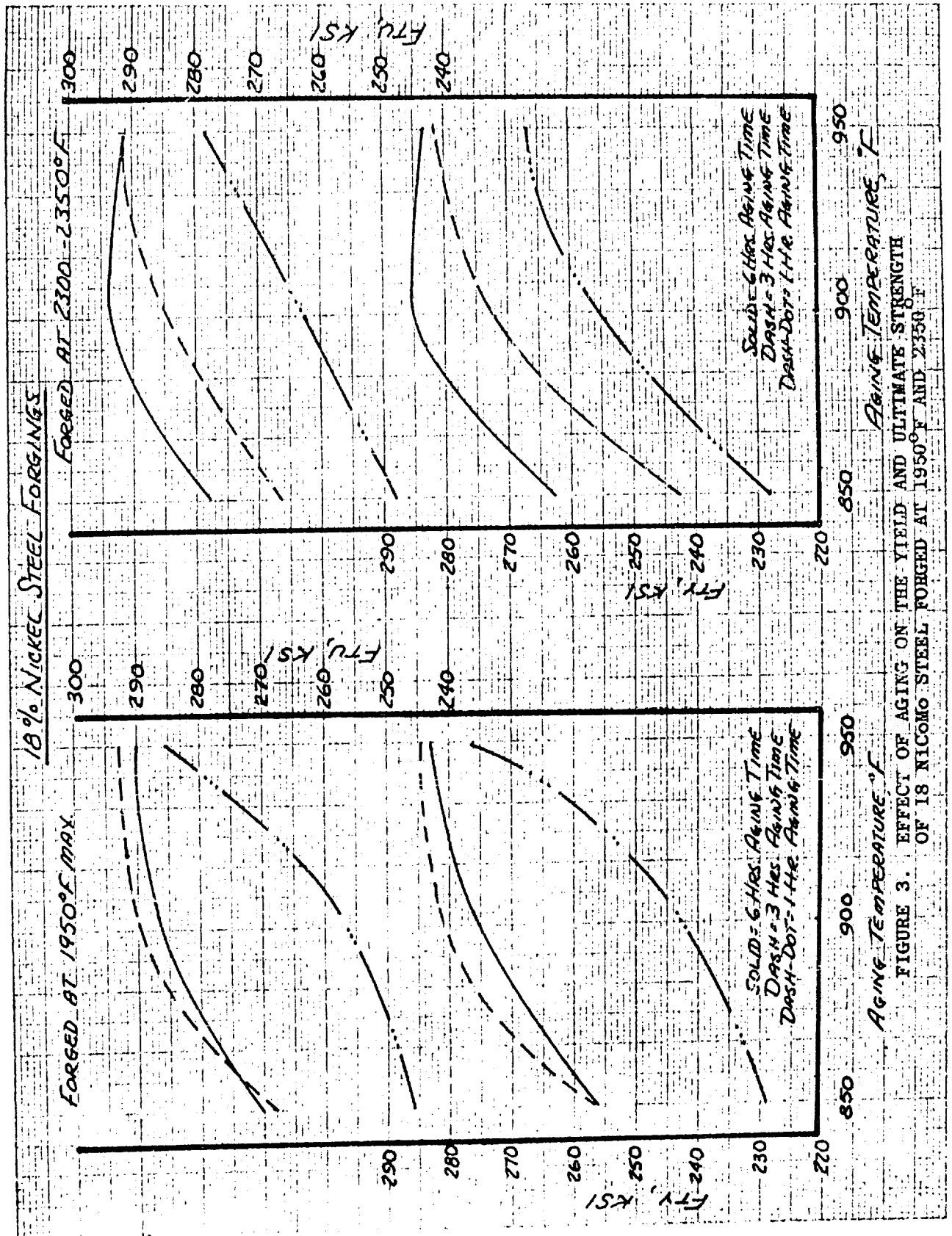
Approx. 1/4"
Scale

FIGURE 2

SPECIMEN LOCATION
IN FORGING

Forged between 2300-2350°F





18% NICKEL STEEL FORGINGS

SOLID = 6 HRS. AGING TIME

DASH = 3 HRS AGAIN: TIME

DASH-DOT = 1 Hr. Aging Time

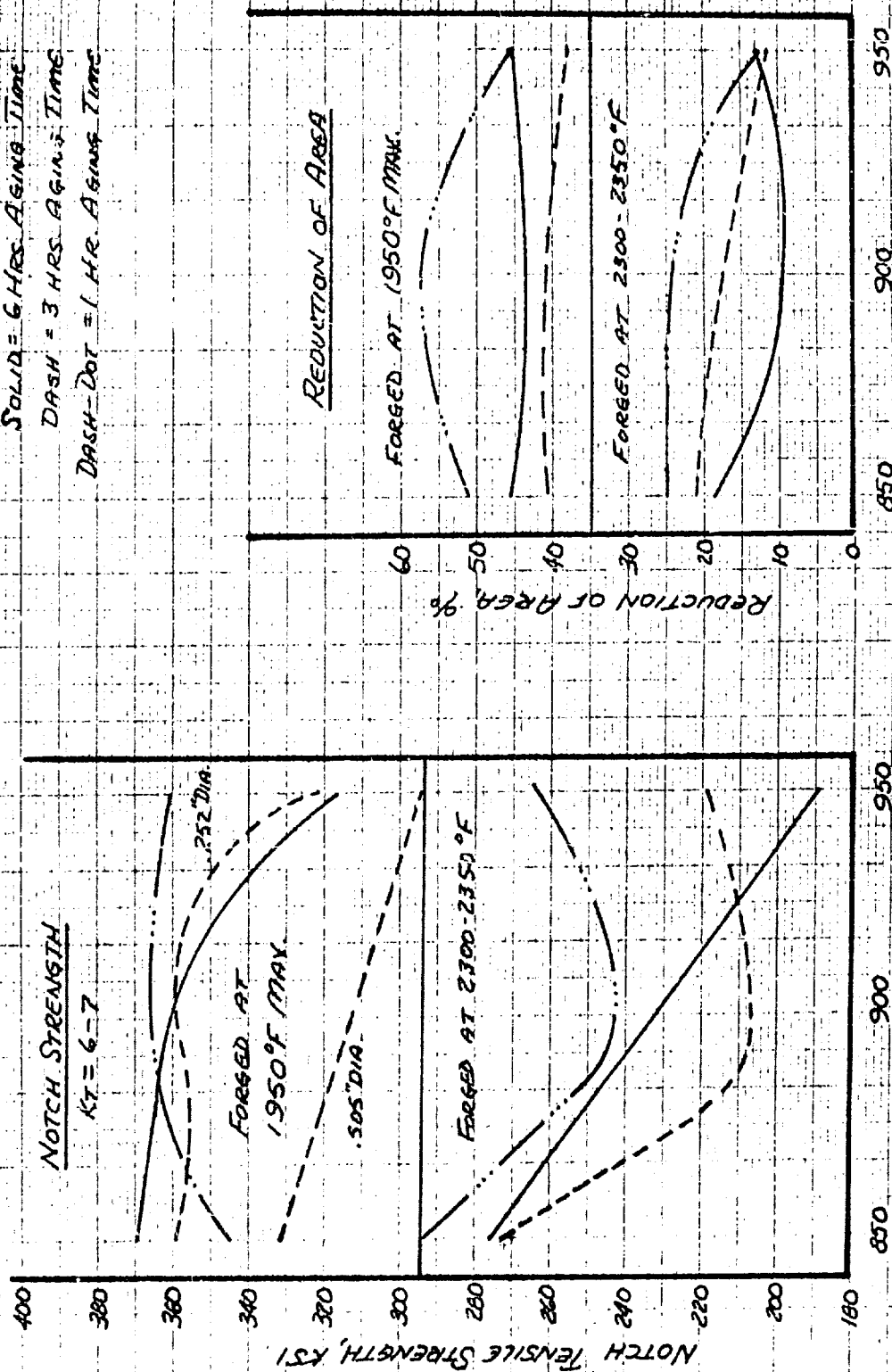


TABLE ICOMPOSITION AND FORGING PROCEDURE OF 18 NiCoMo STEEL

CHEMICAL COMPOSITION

OF 18 NI-CO-MO USED

IN FORGING PROGRAM

VENDOR: Allegheny Ludlum Steel Corporation

HEAT NUMBER: Consutrode #23992

CHEMISTRY:

| | |
|------------|-------|
| Carbon | 0.007 |
| Manganese | 0.02 |
| Silicon | 0.02 |
| Phosphorus | 0.004 |
| Sulphur | 0.004 |
| Nickel | 18.73 |
| Cobalt | 8.75 |
| Molybdenum | 4.92 |
| Titanium | 0.63 |
| Aluminum | 0.11 |
| Boron | 0.003 |

MANUFACTURING PROCEDURE ¹
FOR FORGING 18% NICKEL
IN ACCORDANCE WITH VENDOR
RECOMMENDATIONS

(W FORGINGS ONLY)

1. Cut a single multiple 9" RCS x 290#
 2. Charge into a furnace operating at 1500°F and equalize
 3. Heat to 1950°F at a rate of 200°F/hour and equalize
 4. Forge a "blank" on flat die hammer (2 reheats necessary)
 5. Transfer to a second furnace operating at 1950°F and equalize
 6. Roll on an 8,000# steam hammer in one heat
 7. Transfer to a third furnace operating at 1950°F and equalize
 8. Finish forge on a 12,000# steam hammer. Two reheats necessary plus one flash reheat in order to hot trim flash metal.
NOTE: During finish forging, the 18% Ni was not soaked during reheats in order to prevent or at least minimize grain growth. The forging received in excess of 25% reduction during finish forging (from roller configuration to finish size). It was necessary to "flash" heat for trimming; however, the body of the forging did not exceed 1790°F. Temperature of forging after last hammer blow was approximately 1550/1675°F.
 9. Air Cool after trimming.
 10. Shotblast clean.
1. Information from Kropp Forge, letter DeLazaro (Kropp) to Rusk (GD/FW) dated 15 March 1962.

TABLE II
NOTCH TOUGHNESS PROPERTIES OF 18 NiCoMo (300) MAR-AGING STEEL

| | Aging Temp, °F | Test Temp, °F | Crack Length at Instability | Notch Strength, Ksi | | Shear % | Hardness R _c |
|----|-------------------|------------------|--------------------------------|---------------------|-------------|------------|----------------------------|
| | | | | Gross | Nominal Net | | |
| 1. | 850 | RT | 1.212" | 59.2 | 91.8 | 99.3 | 51.7 |
| 2. | 850 | -65 | - | 49.8 | 76.5 | - | 52.9 |
| 3. | 900 | -65 | - | 43.4 | 66.9 | - | 53.2 |
| 4. | 900 | -65 | - | 47.8 | 73.9 | - | 53.2 |
| 5. | 950 | RT | 1.512" | 54.4 | 84.9 | 109.5 | 53.3 |
| 6. | 950 | -65 | - | 52.4 | 83.2 | - | 53.3 |

1. Specimens from 4" x 12" billet with notch in short transverse direction.
2. All specimens annealed at 1500°F and aged 3 hours at indicated temperature.
3. Fatigue cracks formed by axial tension - tension stress equivalent to 1/5 F_{ty} initially (R = 0.1) and propagated at 1/10 F_{ty} to 1.05" length.

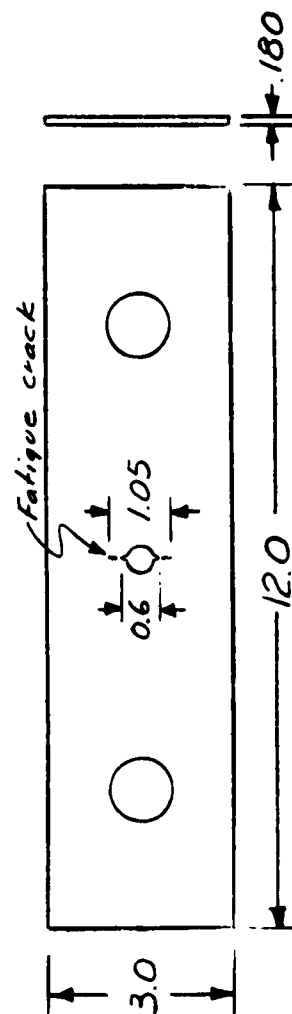


TABLE III
HEAT TREAT RESPONSE OF 18 NiCoMo STEEL FORGING "W"

| Condition | Loca- tion | Grain Direc- tion | Temper Temp, °F | F _{ty} Ksi | F _{tu} Ksi | Elong. % in 4D | % R.A. | Loca- tion | F _{tnu} , Ksi | Notch Ult. Ratio | K _t |
|---|---------------|-------------------------|-----------------------|------------------------|------------------------|----------------------|-----------|---------------|---------------------------|------------------------|----------------|
| Forged at 1950°F max. .250" dia. specimens | H-1 | Long. | 850-1 Hr. | 228.8 | 245.4 | 10.5 | 51.5 | H-2 | 345.2 | 1.41 | 5.7 |
| | -3 | ↓ | -3 Hr. | 246.4 | 263.6 | 11.0 | 50.1 | -4 | 360.0 | 1.37 | 6.3 |
| | -5 | ↓ | -6 Hr. | 255.6 | 269.8 | 9.0 | 45.2 | -6 | 369.6 | 1.37 | 5.7 |
| | H-25 | Long. | 900-1 Hr. | 241.3 | 255.6 | 10.5 | 57.8 | H-8 | 366.5 | 1.43 | 5.7 |
| | -9 | ↓ | -3 Hr. | 261.3 | 278.7 | 9.0 | 44.8 | -10 | 358.4 | 1.29 | 5.7 |
| | -19* | ↓ | -3 Hr. | 266.2 | 306.0 | 10.0 | 51.5 | -20* | 360.1 | 1.18 | 5.7 |
| | -11 | ↓ | -6 Hr. | 275.1 | 286.0 | 8.0 | 43.8 | -12 | 361.2 | 1.26 | 6.2 |
| | H-13 | Long. | 950-1 Hr. | 276.4 | 284.6 | 9.0 | 46.1 | H-14 | 360.4 | 1.27 | 5.7 |
| | -15 | ↓ | 3 Hr. | 275.2 | 286.2 | 10.0 | 49.3 | -16 | 323.2 | 1.13 | 5.7 |
| | -17 | ↓ | 6 Hr. | 282.4 | 290.1 | 8.0 | 45.2 | -18 | 317.8 | 1.10 | 5.7 |
| | E-1 | Long. | 850-3 Hr. | 255.4 | 267.3 | 9.5 | 41.9 | F-1 | 324.0 | 1.21 | 6.5 |
| | -2 | Long. | -3 Hr. | 255.7 | 267.7 | 9.5 | 40.9 | -2 | 334.8 | 1.25 | 6.2 |
| Forged at 1950°F max. .505" dia. specimens | C-11 | Long. | 900-3 Hr. | 269.9 | 281.1 | 10.5 | 44.4 | | | | |
| | E-3 | ↓ | ↓ | 285.4 | 292.8 | 8.5 | 38.4 | F-3 | 316.1 | 1.09 | 6.2 |
| | -7 | ↓ | ↓ | 276.4 | 287.0 | 8.0 | 43.3 | -4 | 312.0 | 1.08 | 6.2 |
| | -8 | ↓ | ↓ | 279.5 | 289.8 | 9.5 | 42.3 | -5 | 309.4 | 1.07 | 6.2 |
| | E-12 | Long. | 950-3 Hr. | 283.3 | 291.4 | 8.0 | 35.2 | F-6 | 293.9 | 1.01 | 6.9 |
| | -13 | Long. | -3 Hr. | 283.2 | 293.1 | 9.0 | 40.3 | -7 | 280.0 | .96 | 6.5 |
| | | | | | | | | -8 | 294.3 | 1.01 | 6.9 |
| | A-1 | S. Tran. | 900-3 Hr. | 274.1 | 287.7 | 7.9 | 26.1 | | | | |
| | -2 | ↓ | ↓ | 273.6 | 287.7 | 7.9 | 26.9 | A-3 | 281.8 | .98 | 6.2 |
| | -7 | ↓ | ↓ | 275.1 | 284.5 | 7.5 | 31.8 | -4 | 227.9 | .79 | 6.2 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

All specimens annealed 4 hours at 1500°F prior to removal from forging.

* Held at -112°F for 16 hours prior to aging.

TABLE IV
HEAT TREAT RESPONSE OF 18 NiCoMo STEEL FORGING "S"

| Condition | Loca- tion | Grain Direc- tion | Temper Temp, °F | F _{ty} Ksi | F _{tu} Ksi | Elong. % in 4D | % R.A. | Loca- tion | F _{tnu} , Ksi | Notch Ult. Ratio | K _t |
|--|---------------|-------------------------|-----------------------|------------------------|------------------------|----------------------|-----------|---------------|---------------------------|------------------------|----------------|
| Forged at 2350°F max. Forging "S" .505" dia. Specimens | F- 1 | Long. | 850-1 Hr. | 227.6 | 247.6 | 6.0 | 24.6 | E- 1 | 293.9 | 1.19 | 6.9 |
| | - 2 | ↓ | -3 Hr. | 242.6 | 266.2 | 5.0 | 21.2 | - 2 | 275.8 | 1.04 | 6.2 |
| | - 3 | | -6 Hr. | 262.2 | 277.7 | 5.0 | 18.3 | - 3 | 275.9 | .99 | 6.9 |
| | F- 4 | Long. | 900-1 Hr. | 255.2 | 263.3 | 6.0 | 24.4 | E- 4 | 240.7 | .91 | 6.9 |
| | - 5 | ↓ | -3 Hr. | 273.0 | 284.4 | 3.5 | 17.4 | - 5 | 206.4 | .73 | 6.9 |
| | -10* | ↓ | -3 Hr. | 269.8 | 280.8 | 3.0 | 11.9 | -10* | 271.3 | .97 | 5.9 |
| | - 6 | | -6 Hr. | 285.3 | 294.7 | 3.0 | 9.1 | - 6 | 232.7 | .80 | 6.2 |
| | F- 7 | Long. | 950-1 Hr. | 266.8 | 278.4 | 3.0 | 13.3 | E- 7 | 273.0 | .98 | 6.2 |
| | - 8 | ↓ | -3 Hr. | 281.3 | 291.9 | 3.0 | 11.2 | - 8 | 218.5 | .75 | 6.2 |
| | - 9 | ↓ | -6 Hr. | 283.5 | 291.5 | 3.0 | 12.5 | - 9 | 188.9 | .65 | 6.2 |

All specimens annealed 4 hours at 1500°F prior to removal from forging.

* Held at -112°F for 16 hours prior to aging.

Inquiries for additional information on
this program should be addressed to

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